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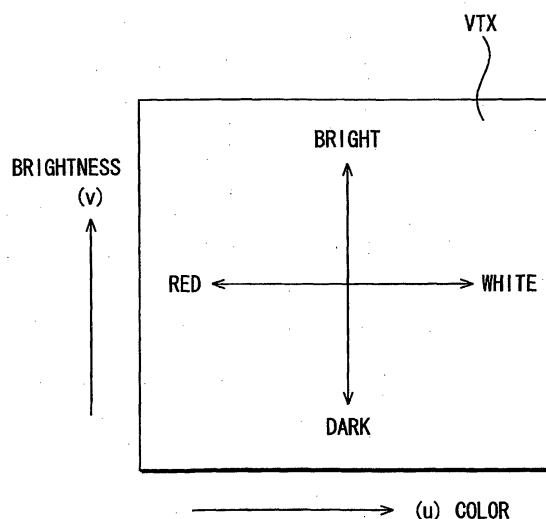
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(54) **PAINTING METHOD**

(57) A rendering processing device holds a table which contains color and brightness values at positions specified by two-dimensional coordinates, where color tone gradually varies in a direction of one coordinate axis of the two-dimensional coordinate, and brightness gradually varies in a direction of the other coordinate axis. The rendering processing device finds parameters corresponding to color and brightness to be rendered, and generates an address for referencing a two-dimensional coordinate corresponding to each pixel composing a polygon based on the parameters. The rendering processing device then acquires from the table color and brightness values corresponding to the address for referencing the two-dimensional coordinate. This successfully realizes natural expression by the rendering processing device without preparing in advance a huge number of textures.

FIG. 1



Description

TECHNICAL FIELD

[0001] The present invention relates to a rendering processing method and device for rendering three-dimensional image information on a two-dimensional screen such as on a television monitor device, a recording medium having recorded therein a rendering processing program, and such rendering processing program.

BACKGROUND ART

[0002] There are accelerating trends in higher integration and faster processing speed of processors and memories in recent television game consoles and personal computers, so that an image rendering device composed of such a game console or personal computer can generate, from three-dimensional image information, fine two-dimensional images with high quality and diversity, and with real presence in a real-time manner, and can display them on two-dimensional monitor screens.

[0003] When a three-dimensional image is rendered on a two-dimensional screen, the image rendering device subjects three-dimensional polygon data to geometry processing, such as coordinate conversion processing, clipping and lighting processing, and further subjects the data after the geometry processing to transparent projection conversion processing. The image rendering device also pastes textures having various colors and patterns onto surfaces of polygons to thereby give desired colors and patterns to the objects. Such pasting of textures onto polygons is generally referred to as texture mapping.

[0004] By employing a rendering technique described below, the image rendering device can generate a so-called specular image, which is an image expressing a water surface or the like having a light source caught thereon. To render the specular image, the image rendering device first sets R, G and B values for the individual apexes of polygons in an area where the light source will be caught in accordance with brightness of the light source. The image rendering device then performs linear interpolation between the brightness of respective apexes through processing such as so-called flat shading or Gouraud shading.

[0005] According to this rendering technique, R, G and B values will change in a linear manner between respective apexes of polygons, and therefore adjacent polygons may have considerably different brightnesses. It is thus difficult to express a natural specular image with such rendering technique.

[0006] The image rendering device may employ another rendering technique described below to generate an image having a light source caught on a water surface and so forth. The image rendering device in this

case has stored therein as many textures as possible which are previously prepared in order to cope with differences in the brightness of the light source or colors. The image rendering device finds R, G and B values for the individual apexes of polygons based on normal line vectors of the polygon apexes, line-of-sight vectors, the direction of the light source, and the color and brightness of the light source, and performs texture mapping corresponding to the R, G and B values of the individual apexes. Such rendering technique is characterized in that it can express the sun or moon caught on the water surface more naturally as compared with the foregoing rendering technique.

[0007] This rendering technique is, however, requires a vast number of textures so as to cope with differences in the brightness of the light source or color.

[0008] Assuming now that the light source is the sun or moon, for example, the actual sun or moon looks different in color or brightness depending on its altitude from the ground (i.e., elevation angle) and the weather conditions (clear, slightly cloudy, humidity in the air, airborne dust). The apparent color and brightness of the sun or moon also vary over time due to travel thereof (i.e., apparent movement due to the autorotation of the earth). Therefore, when rendering an image having the sun or moon caught on the water surface, in order to achieve a more natural expression, the image rendering device should preliminarily prepare and store a huge number of textures capable of expressing all apparent colors and brightnesses which correspond to the altitude of the sun or moon or weather conditions and which vary over time. Moreover, reflectivity on the water surface can vary depending on the incident angle of light coming onto the water surface and the angle of reflection of light reflected from the water surface, that is, depending on the angle between line-of-sight and the water surface. This also forces the image rendering device to preliminarily store and prepare a drastically increased number of textures in order to express all variations of such reflectivity.

[0009] The present invention was proposed to address the foregoing problems, and an object thereof resides in providing a rendering processing method and device especially capable of achieving more natural expression of the sun or moon caught on the surface of water without preparing a huge number of textures, and also resides in providing a recording medium having recorded thereon a rendering processing program, and such rendering processing program.

DISCLOSURE OF THE INVENTION

[0010] According to the present invention, parameters corresponding to the color or brightness to be rendered are added to apex information of a polygon, and based on such parameters an address for referencing a two-dimensional coordinate corresponding to each pixel composing such polygon is generated. Color and

brightness values corresponding to the address are then acquired and assigned to the individual pixels, from a table containing color and brightness values at positions specified by two-dimensional coordinates where one coordinate axis of the two-dimensional coordinates expresses a gradation of color tone, and the other coordinate axis of the two-dimensional coordinate expresses a gradation of brightness. The table is provided as a texture.

[0011] In other words, the present invention sets color and brightness values of a polygon in which a light source will be caught by acquiring color and brightness values of the individual pixels from a table based on two-dimensional coordinate values added to such polygon. The present invention achieves rendering of a polygon having a light source caught thereon by using such table as a texture through a process similar to the general texture mapping without the need for special processing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a drawing for explaining a vertex color texture;

FIG. 2 is a drawing for explaining how to find a specular component and how to decide parameters v for polygon apexes;

FIG. 3 is a drawing for explaining a vertex color texture having daytime and nighttime colors based on zonal division;

FIG. 4 is a drawing for explaining a vertex color texture having daytime and nighttime colors, and sunlight and moonlight colors based on zonal division;

FIG. 5 is an image of an exemplary scene having sunlight caught on the ocean surface prepared by using the vertex color texture shown in FIG. 4;

FIG. 6 is a block diagram of an exemplary constitution for realizing the rendering process;

FIG. 7 is a block diagram of a schematic constitution of a computer for realizing the rendering process; and

FIG. 8 is a flow chart of a process for achieving rendering processing by a computer.

BEST MODE FOR CARRYING OUT THE INVENTION

[0013] The image rendering device of the present invention has stored in a buffer thereof a table VTX composed individual value expressing color and brightness as shown in FIG. 1.

[0014] The individual values for expressing color and brightness in the table VTX are addressable by parameters u and v which are two-dimensional coordinate values. The value of the parameter u shown in FIG. 1 gradually increases from left to right along the direction of the abscissa in this drawing, and the value of the parameter v gradually increases from bottom to top along

the direction of the ordinate. The table VTX is also designed to have color tones vary gradually in correspondence to the gradual changes in the parameter u , and to have brightness vary gradually in correspondence to the gradual changes in the parameter v . In other words, the table VTX has gradation both in the changes in color along the direction of the abscissa in the drawing, and in the changes in brightness along the direction of the ordinate. Of course, the table VTX in FIG. 1 merely shows one example, so that it is also possible for brightness to be expressed by the parameter u and color by the parameter v . Color gradations may conceivably include, beside a gradation by which the color tone gradually changes from red to white as illustrated in FIG. 1, gradations from blue→black, blue→red, and white (or light yellow)→orange→red→ultramarine blue→black. Brightness gradations may conceivably include, beside a gradation shown in FIG. 1 in which the brightness changes from "dark" to "bright" as the parameter v becomes larger, an inversed case thereof. The image rendering device may store different color tables VTX in the buffer.

[0015] The table VTX can be provided as a texture since the table is composed of the individual values for expressing color and brightness. In the present embodiment, the table VTX shown in FIG. 1 is now defined to be stored in a texture buffer as one texture. That is, the table VTX is stored in the texture buffer as one texture which comprises texels respectively having color and brightness values. Of course, the texture buffer stores general textures used for so-called texture mapping. It should now be noted that the table VTX is specifically referred to as vertex color texture VTX.

[0016] In the rendering of a specular image in which a light source is caught on a polygon surface which composes a water surface or the like, the image rendering device first determines the color and brightness to be rendered, and determines parameters to be assigned to the apexes of the polygon for texture mapping (hereinafter referred to as texture addresses U , V) corresponding to such color and brightness to be rendered. The image rendering device then sets the texture addresses U , V to the parameters u , v of the vertex color texture VTX shown in FIG. 1. In other words, the vertex color texture VTX herein is used as a lookup table for deciding the brightness and color of the apexes of the polygon. The image rendering device then finds addresses for making reference to texels corresponding to the individual pixels in the polygon, makes reference to the color and brightness in the vertex color texture VTX using the parameters u , v corresponding to the addresses for making reference to the texels, and then maps them onto the polygon. As described above, the color and brightness values in the vertex color texture VTX are aligned in a gradated manner, from which various colors are available, so that the image rendering device can artificially realize a variety of interpolations of color and brightness within the polygon.

[0017] The following paragraphs describe how the image rendering device can determine the parameters u , v for the polygon apexes and can assign the color and brightness thereto, referring to FIG. 2 in which a specular image having sunlight caught on the water surface is rendered. It should be noted that all sizes of vectors L , n , E , R are normalized to "1" in FIG. 2 for the convenience of explanation.

[0018] The explanation will start with a method for deciding a parameter v .

[0019] The image rendering device finds the brightness of a polygon PG composing the water surface in which the sun (referred to as a light source 1s) will be caught, where the found brightness is determined as the size of a specular component. More specifically, the image rendering device finds a normal line vector n which stands at a certain point pt on the polygon PG and a light source vector L between such point pt and the light source 1s, and then finds a reflection vector R based on the light source vector L and the normal line vector n . Next, the image rendering device finds a line-of-sight vector E between such point pt towards the point of view PV, and further finds the angle θ between the line-of-sight vector E and the reflection vector R . The image rendering device finally finds the cosine value a of the angle θ between the line-of-sight vector E and the reflection vector R , which value is assumed as the size of the specular component.

[0020] Assuming now the cosine value a of the angle θ between the line-of-sight vector E and the reflection vector R is equal to 1 (i.e., $\theta = 0^\circ$), light reflected from the light source 1s will look the brightest since the specular component will be a maximum. On the contrary, assuming now the cosine value a of the angle θ between the line-of-sight vector E and the reflection vector R is equal to 0 (i.e., $\theta = 90^\circ$), reflected light of the light source 1s will not be visible from the point of view PV since the specular component will be 0. In other words, the specular component increases as the angle θ decreases, and the specular component decreases as the angle θ increases.

[0021] Accordingly, the image rendering device will successfully introduce the light from the light source onto the polygon with a brightness corresponding to the angle θ by selecting the parameter v depending on the cosine value a which varies from 0 to 1 for expressing the specular component, and by making reference to the brightness value from the vertex color texture VTX using such parameter v . In other words, the image rendering device selects a larger value for the parameter v as the angle θ becomes smaller, and a smaller value for the parameter v as the angle θ becomes larger. Using such parameter v in order to make reference to the brightness value from the vertex color texture VTX, the image rendering device can render a specular image having the light source caught on the polygon in a brightness which depends on the angle θ between the line-of-sight vector E and the reflection vector R .

[0022] In a more specific example of processing, the image rendering device selects the parameter v from the vertex color texture VTX assuming $f(a) = v$, where $f(a)$ is a function using, as an argument, the cosine value a of the angle θ between the line-of-sight vector E and the reflection vector R , and assigns such parameter v to the individual apexes $v1$, $v2$, $v3$, $v4$ of the polygon PG.

[0023] This allows the image rendering device to successfully express the brightness depending on the specular component.

[0024] The next paragraphs will describe a method for determining the parameter u . It is to be noted that the example herein deals with a method for determining the parameter u for the case in which the color of the light source caught on the polygon PG composing the water surface varies over time. For the case using the vertex color texture VTX in which the color tone varies from white to red in a gradated manner as the value of parameter u decreases, as shown in FIG. 1, the image rendering device will be successful in expressing a transient scene from daytime to evening in which the sunlight gradually turns to red to display an evening glow if value of the parameter u is gradually decreased with the elapse of time.

[0025] When the color of the light source caught on the polygon is to be varied over time, the image rendering device selects the parameter u from the vertex color texture VTX assuming $g(t) = u$, where $g(t)$ is a function using time t as an argument, and assigns such parameter u to the individual apexes $v1$, $v2$, $v3$, $v4$ of the polygon PG.

[0026] By thus setting the parameter u , which varies over time, as texture addresses U for the polygon apexes $v1$, $v2$, $v3$, $v4$, the image rendering device can express a scene in which the color of a portion where the light source is caught will vary over time. It is, of course, possible for the image rendering device to assign the parameter v to the polygon apexes assuming $g(t) = v$, to thereby vary the brightness of the light source caught on such polygon with the elapse of time.

[0027] Next, as another example, it is possible to use the vertex color texture VTX having zones bounded by the parameter u of a certain value, where the divided zones have different colors. FIG. 3 shows a vertex color texture VTXa divided by a line segment expressed by pu in the figure, where a zone 81 corresponding to the parameter u in the region below the boundary expressed by the line segment pu contains daytime-related colors (e.g., the color of sunlight caught on the ocean surface in the daytime), and a zone 82 corresponding to the parameter u in the region above the boundary expressed by the line segment pu contains nighttime-related colors (e.g., the color of moonlight caught on the ocean surface in the nighttime). By using such vertex color texture VTXa, the image rendering device can effectively express the catching of the light source both in the daytime scene and the nighttime scene.

[0028] In other words, by using the vertex color tex-

ture VTXa shown in FIG. 3 and selecting the parameter u while assuming $g(t) = u$, the image rendering device will successfully realize a rendering in which the catching of the light will continuously vary from the daytime scene to the nighttime scene with the elapse of time.

[0029] A more natural expression of the caught light transient from the daytime to the evening and then to the nighttime will be available if a zone corresponding to the colors of the setting sun caught on the ocean surface in the evening is provided between the zone 81 corresponding to the colors of the sunlight caught on the ocean surface in the daytime and the zone 82 corresponding to the colors of the moonlight caught on the ocean surface in the nighttime.

[0030] In a still another example, the vertex color texture VTX may be divided in the direction of the parameter v as well as in the direction of the parameter u as shown in FIG. 4. The vertex color texture VTXb shown in FIG. 4 is divided by line segments expressed by pu and p_v in the drawing. In such vertex color texture VTXb, a zone 83 corresponding to the parameter u in the region below the boundary expressed by the line segment pu and the parameter v in the region below the boundary expressed by the line segment p_v typically is provided with colors of the ocean surface in the daytime. A zone 81 corresponding to the parameter u in the region below the boundary expressed by the line segment pu and the parameter v in the region above the boundary expressed by the line segment p_v is provided with colors of the sunlight caught on the ocean surface in the daytime. A zone 84 corresponding to the parameter u in the region above the boundary expressed by the line segment pu and the parameter v in the region below the boundary expressed by the line segment p_v contains colors of the ocean surface in the nighttime. A zone 82 corresponding to the parameter u in the region above the boundary expressed by the line segment pu and the parameter v in the region above the boundary expressed by the line segment p_v is provided with color of the moonlight caught on the ocean surface in the nighttime.

[0031] Also in the example shown in FIG. 4, by selecting the parameter u while assuming $g(t) = u$, the image rendering device will successfully realize a rendering in which the catching of the light will continuously vary from the daytime scene to the nighttime scene with the elapse of time similarly to the example shown in FIG. 3. A more natural expression of the caught light transient from the daytime to the evening and then to the nighttime will be available if the vertex color texture VTX to be employed has a zone corresponding to the colors of the ocean surface during evening glow and a zone corresponding to the colors of the setting sun.

[0032] FIG. 5 is an exemplary scene rendered using the vertex color texture VTXb shown in FIG. 4, in which a daytime sunlight RSU is caught on the ocean surface OC. FIG. 5 shows a specific case containing the sky SK and the ocean surface OC onto which the sunlight RSU

is caught.

[0033] To perform the rendering shown in FIG. 5, the image rendering device selects the parameters u and v contained in the zone 81 of the vertex color texture VTXb shown in FIG. 4 for a portion where the cosine value a of the angle θ between the line-of-sight vector E and reflection vector R shown in FIG. 2 will be equal to or near 1, that is, for a portion where the light source (sun) is expected to be caught. On the other hand, the image rendering device selects the parameters u and v contained in the zone 83 of the vertex color texture VTXb shown in FIG. 4 for a portion where the cosine value a of the angle θ between the line-of-sight vector E and reflection vector R shown in FIG. 2 will be equal to or near 0, that is, for a portion where the light source (sun) will not be caught. Such selection of the parameters u and v from the zone 81 for the portion expected to catch the sun, and from the zone 83 for the portion not expected to catch the sun will successfully achieve a natural expression of the catching of the light as shown in FIG. 5, in which the ocean surface OC will have caught thereon the sun in a certain degree of size, and will have gradation in the color and brightness in the caught sunlight and the surrounding ocean surface OC.

[0034] The image rendering device can change the color of the ocean surface OC into the nighttime color by using the vertex color texture VTXb shown in FIG. 4, selecting the parameters u , v from the zone 82 for the moonlight portion caught on the ocean surface, and selecting the parameters u , v from the zone 84 for the ocean surface portion which does not catch the moonlight, to thereby obtain an expression that the sunlight RSU in FIG. 5 is altered to moonlight.

[0035] In still another example, each texel in the vertex color texture VTX may have an α value expressing transparency. The α value in this case has a value which varies corresponding to the gradated changes in the parameter v along the direction of the ordinate. For the case that each texel value in the vertex color texture VTX has an α value, the image rendering device can typically achieve a rendering in which the water surface is expressed as semi-transparent depending on the angle between the line of sight and the line normal to the water surface, that is, a rendering capable of expressing variations in the reflectivity of the water surface.

[0036] FIG. 6 shows a specific constitution of the image rendering device for realizing the foregoing rendering process. It is to be noted that the image rendering device of the present embodiment relates to an exemplary case in which the rendering process of the present embodiment is realized on a hardware basis using a digital signal processor (DSP), a graphic processor (GP) or the like. For the case the rendering process is carried out by a DSP or GP, the individual components shown in FIG. 6 correspond to the internal processing unit of the DSP or GP.

[0037] In FIG. 6, a memory 51 stores graphic information of polygons or the like (apex information or apex-

linked information such as coordinate values for apexes, RGB apex color values, map coordinate values and vector values). The graphic information herein may be taken in from various recording media such as a CD-ROM, DVD-ROM or semiconductor memory, or through communication or transmission media based on line or radio communications.

[0038] A geometry calculating section 50 reads out stored graphic information from the memory 51, and then subjects the retrieved graphic information to so-called affine transformation, projection conversion onto a screen coordinate, light source processing for the apexes, matrix calculation and vector calculation.

[0039] The geometry calculating section 50 has a parameter deciding section 60 which is responsible for determining the parameter u depending on the color to be rendered, and at the same time for determining the parameter v based on the light source $1s$, light source vector L , normal line vector n , point of view PV , line-of-sight vector E , reflection vector R , and cosine value a (specular component) of the angle θ between the line-of-sight vector E and the reflection vector R explained above with reference to FIG. 2. In particular, for determining the parameter v which relates to the brightness of the light source caught on the polygon surface, the parameter deciding section 60 finds the light source vector L , normal line vector n of the polygon, reflection vector R and line-of-sight vector E , and then determines the parameter v based on the cosine value a (specular component) of the angle θ between the reflection vector R and line-of-sight vector E . Varying the parameter u over time by the parameter deciding section 60 will result in varying color with the elapse of time.

[0040] The graphic information (polygon data) output from the geometry calculating section 50 is sent to a rendering section 52. The rendering section 52 is responsible for calculations to display polygons on the screen, and converts the polygon data received from the geometry calculating section 50 into pixels. The rendering section 52 can roughly comprise a polygon setup/rasterizing section 61 (hereinafter referred to as PSR section 61), a pixel pipeline section 62 and a frame buffer 63.

[0041] The rendering section 52 is accompanied by a texture buffer 55 and a Z buffer 56. The texture buffer 55 stores at least a normal texture 68 and the vertex color texture VTX. The Z buffer 56 stores Z values for expressing depth-wise distance of the image from the point of view. The vertex color texture VTX, normal texture 68 and Z values are taken in from various recording media such as a CD-ROM, DVD-ROM or semiconductor memory, or through communication or transmission media based on line or radio communications.

[0042] The PSR section 61 of the rendering section 52 is responsible for taking in and buffering of polygon data received from the geometry calculating section 50, and for pixel conversion and calculation of texel coordinate values (addresses for referencing two-dimensional

coordinates) through rasterizing processing. The PSR section 61 is responsible for finding texel coordinate values for referencing the vertex color texture VTX using the parameters u , v of the polygon apexes. It is to be noted that for the case of pasting the general texture onto the polygon, the PSR section 61 generates the texel coordinate values for referencing the general texture 68. The PSR section 61 then sends the individual pixel data and texel coordinate values to the pixel pipeline section 62.

[0043] The pixel pipeline section 62 refers to the general texture 68 stored in the texture buffer 55 or to the texel color stored in the vertex color texture VTX using such texel coordinate values, and then performs texture mapping while taking the Z values in the Z buffer 56 into consideration. The pixel data output from the pixel pipeline section 62 after texture mapping is sent to the frame buffer 63.

[0044] The frame buffer 63 writes each pixel data at least in a memory space corresponding to a display (screen) of a television monitor or the like so as to correspond each pixel with the screen coordinate of such display. The frame-wise screen data thus generated by the frame buffer 63 is read out thereafter upon being requested by a display controller 53.

[0045] The display controller 53 generates horizontal synchronizing signals and vertical synchronizing signals of the television monitor, and also serially takes out pixel color values from the frame buffer 63 in a line-feed manner in synchronization with the display timing of the monitor. The taken out color values compose a two-dimensional image which will be displayed on a display 54, such as a television monitor.

[0046] The image rendering process of the present embodiment is not realized only by a hardware constitution, but of course also can be achieved on a software basis (using application programs for computers). FIGS. 7 and 8 show the constitution and operation of the image rendering process of the present embodiment as executed on a computer. FIG. 8 shows a process flow according to which a CPU 123 of the computer executes the image rendering program of the present invention.

[0047] In FIG. 7, a storage unit 128 typically comprises a hard disk and a drive therefor. Such storage unit 128 has stored therein an operating system program, a computer program 129 including the image rendering program of the present embodiment read out from various recording media such as a CD-ROM or DVD-ROM or downloaded through a communication line, and a variety of data 130 such as graphic information for polygon rendering, general texture, vertex color texture VTX and Z values.

[0048] A communication unit 121 is a communication device responsible for data communication with external devices, which may be a modem for establishing a connection to an analog public telephone line, a cable modem for establishing a connection to a cable television network, a terminal adaptor for establishing a con-

nection to an ISDN (integrated services digital network), or a modem for establishing a connection to an ADSL (asymmetric digital subscriber line). A communication interface (I/F) unit 122 is an interface device responsible for protocol transfer for enabling the sending and receiving of data between the communication unit 121 and an internal bus (BUS).

[0049] An input unit 133 is an input device such as a keyboard, mouse or touch pad. A user interface (I/F) unit 132 refers to an interface device for supplying signals from such input unit 133 to the internal devices.

[0050] A drive unit 135 is a drive device capable of reading out various data or programs from a recording medium, including a disk medium 151 such as a CD-ROM, DVD-ROM or floppy (trademark) disk, or from a card-type or other type of semiconductor memory. A drive interface (I/F) unit 134 is an interface device for supplying signals from such drive unit 135 to the internal devices.

[0051] A display unit 137 is a display device such as a CRT (cathode ray tube) or liquid crystal display. A display drive unit 136 is a device for driving such display unit 137.

[0052] The CPU 123 controls the entire operation of the personal computer based on the operating system program stored in the storage unit 128 or the computer program 129 of the present embodiment.

[0053] A ROM 124 typically comprises a rewritable non-volatile memory such as a flash memory, and stores a BIOS (basic input/output system) and various default values of the personal computer. A RAM 125 will have loaded therein application programs and various data read out from the hard disk of the storage unit 128, and is used as a work RAM of the CPU 123.

[0054] In the constitution shown in FIG. 7, the CPU 123 can accomplish the image processing as described above by executing the image rendering program of the present embodiment, which is read out from the storage unit 128 and loaded into the RAM 125.

[0055] The next paragraphs will describe, referring to FIG. 8, the process flow which takes place when the CPU 123 of the computer shown in FIG. 7 operates based on the image rendering program of the present embodiment.

[0056] In step S1 shown in FIG. 8, the CPU 123 reads from the storage unit 128 graphic information for polygon rendering, general texture, vertex color texture VTX and Z values which are, for example, preliminarily stored therein as data 130, and then has the RAM 125 hold them.

[0057] The CPU 123 then, in step S2, reads out the graphic information held by the RAM 125, subjects the graphic information to affine conversion and projection conversion onto a screen coordinate, and at the same time determines the parameter u , and further determines the parameter v based on the light source $1s$, light source vector L , normal line vector n , point of view PV , line-of-sight vector E , reflection vector R , and cosine

value a (specular component) of angle θ between the line-of-sight vector E and reflection vector R .

[0058] The CPU 123 then, in step S3, performs rasterizing and calculation of texel coordinate values using the polygon data obtained by the geometric calculation.

[0059] Then, in step S4, the CPU 123 generates the texel coordinate values from the parameters of the polygon apexes, refers to the texel colors in the general texture or vertex color texture VTX using such texel coordinate values, and then performs texture mapping.

[0060] The CPU 123 then, in step S5, generates a screen image from the pixel data after the texture mapping, and in step S6 sends information on such screen image to the display drive 136. An image will thus appear on the display unit 137.

[0061] As has been described above, the image rendering device of the present embodiment can successfully achieve a natural expression of the sun or moon caught on the water surface by setting the parameters u , v of the polygon apexes depending on the color and brightness of the polygon to be rendered, and by determining the color and brightness of each pixel by selecting them from the vertex color texture VTX. Also, the image rendering device can achieve a natural expression of a light source caught on the polygon surface without preparing a huge number of textures.

[0062] Since the image rendering device of the present embodiment uses the vertex color texture VTX composed of general texel color data such as R , G , B values and an α value, it is not necessary to prepare special data or to provide a constitution for special processing, and therefore the process load of the rendering section or CPU will not increase.

[0063] Since the image rendering device varies the parameters u , v with the elapse of time during the rendering, the color and brightness can be expressed as variable over time which successfully realizes a more natural rendering.

[0064] Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present invention as defined by the appended claims. That is, the image rendering process of the present embodiment is also applicable to various expressions other than where the light source is caught on the polygon surface. The vertex color texture VTX may not always be prepared in advance, and instead may be produced by the image rendering program immediately before the rendering process is actually started. The image rendering process of the present embodiment can be realized not only on specialized video game consoles or personal computers, but also on various information processing devices including personal digital assistants.

INDUSTRIAL APPLICABILITY

[0065] The present invention is applicable to rendering processing for generating two-dimensional information which is to be rendered on a two-dimensional screen such as television monitors, from three-dimensional information in video game consoles or personal computers.

Claims

1. A rendering processing method, comprising:

determining parameters which correspond to color and brightness;
 adding the determined parameters to apex information of a polygon;
 acquiring from a table values of the color and brightness corresponding to the parameters added to the apex information, the table containing color and brightness values at positions specified by two-dimensional coordinates, color tone gradually varying in a direction of one coordinate axis of the two-dimensional coordinates, and brightness gradually varying in a direction of the other coordinate axis of the two-dimensional coordinates;
 generating an address for referencing a two-dimensional coordinate corresponding to each pixel composing the polygon based on the parameters added to the apex information; and
 referencing the values of the color and brightness from the table based on the address and assigning to each pixel of the polygon.

2. The rendering processing method according to Claim 1, wherein the table has values for expressing a transparency ratio used for pixel rendering at positions specified by two-dimensional coordinates.

3. The rendering processing method according to Claim 1 or 2, wherein the step of determining the parameters further comprises:

finding a specular component generated by catching a light source on a surface of the polygon; and
 determining a parameter which corresponds to brightness based on the specular component.

4. The rendering processing method according to any one of Claims 1 to 3, further comprising:

altering the parameters determined depending on the at least one of the color or brightness to be rendered with the elapse of time.

5. The rendering processing method according to any one of Claims 1 to 4, wherein the table has zones divided based on at least one of color tone and brightness.

6. The rendering processing method according to any one of Claims 1 to 5, wherein the table is provided as a plurality of tables based on at least one of color tone and brightness.

7. The rendering processing method according to any one of Claims 1 to 6, wherein the table comprises a texture having the color and brightness values in the individual texels specified by the parameters or addresses for referencing the two-dimensional coordinate.

8. An rendering processing device, comprising:

a table holding section operable to hold information of a table, the table containing color and brightness values at positions specified by two-dimensional coordinates, color tone gradually varying in a direction of one coordinate axis of the two-dimensional coordinates, and brightness gradually varying in a direction of the other coordinate axis of the two-dimensional coordinates;

a parameter deciding section operable to determine parameters which correspond to color and brightness to be rendered;

an information adding section operable to add the parameters to apex information of a polygon;

an acquiring section operable to acquire from the table values of the color and brightness which correspond to the parameters added to the apex information;

an address generating section operable to generate an address for referencing a two-dimensional coordinate corresponding to each pixel composing the polygon based on the parameters added to the apex information; and

an assigning section operable to refer to the values of the color and brightness from the table based on the address and to assign to each pixel composing the polygon.

9. The rendering processing device according to Claim 8, wherein the table holding section holds information of the table provided with values for expressing a transparency ratio used for pixel rendering at positions specified by two-dimensional coordinates.

10. The rendering processing device according to Claim 8 or 9, wherein the parameter deciding section includes a specular component generating sec-

tion operable to find a specular component generated by catching a light source on a surface of the polygon, and to determine a parameter which corresponds to brightness based on the specular component.

11. The rendering processing device according to any one of Claims 8 to 10, wherein the parameter deciding section alters the parameters determined depending on the at least one of the color or brightness to be rendered with the elapse of time.

12. The rendering processing device according to Claims 8 to 11, wherein the table holding section holds the information of the table in zones divided based on at least one of color tone and brightness.

13. The rendering processing device according to any one of Claims 8 to 12, wherein the table holding zone holds information of a plurality of tables provided based on at least one of color tone and brightness.

14. The rendering processing device according to any one of Claims 8 to 13, wherein the table holding section holds texture information which comprises a texture having the color and brightness values in the individual texels specified by the parameters or addresses for referencing the two-dimensional coordinate.

15. A computer-readable recording medium having recorded thereon an rendering processing program, the rendering processing program comprising:

a step of holding information of a table, the table containing color and brightness values at positions specified by two-dimensional coordinates, color tone gradually varying in a direction of one coordinate axis of the two-dimensional coordinates, and brightness gradually varying in a direction of the other coordinate axis of the two-dimensional coordinates;

a step of determining parameters which correspond to color and brightness to be rendered;

a step of adding the parameters to apex information of a polygon;

a step of acquiring from the table values of the color and brightness which correspond to the parameters added to the apex information;

a step of generating an address for referencing a two-dimensional coordinate corresponding to each pixel composing the polygon based on the parameters added to the apex information; and

a step of referencing the values of the color and brightness from the table based on the address and assigning to each pixel composing the polygon.

16. The computer-readable recording medium according to Claim 15, wherein the table has values for expressing a transparency ratio used for pixel rendering at positions specified by two-dimensional coordinates.

17. The computer-readable recording medium according to Claim 15 or 16, wherein the rendering processing program further comprises:

a step of finding a specular component generated by catching a light source on a surface of the polygon; and

a step of determining a parameter which corresponds to the brightness based on the specular component.

18. The computer-readable recording medium according to any one of Claims 15 to 17, wherein the rendering processing program further comprises a step of altering the parameters determined depending on the at least one of the color and brightness to be rendered with the elapse of time.

19. The computer-readable recording medium according to any one of Claims 15 to 18, wherein the table has zones divided based on at least one of color tone and brightness.

20. The computer-readable recording medium according to any one of Claims 15 to 19, wherein the table is provided as a plurality of tables based on at least one of color tone and brightness.

21. The computer-readable recording medium according to any one of Claims 15 to 20, wherein the table comprises a texture having the color and brightness values in the individual texels specified by the parameters or addresses for referencing the two-dimensional coordinate.

22. A rendering processing program comprising:

a step of holding information of a table, the table containing color and brightness values at positions specified by two-dimensional coordinates, color tone gradually varying in a direction of one coordinate axis of the two-dimensional coordinates, and brightness gradually varying in a direction of the other coordinate axis of the two-dimensional coordinates;

a step of determining parameters which correspond to color and brightness to be rendered;

a step of adding the parameters to apex information of a polygon;

a step of acquiring from the table values of the color and brightness which correspond to the parameters added to the apex information;

a step of generating an address for referencing a two-dimensional coordinate corresponding to each pixel composing the polygon based on the parameters added to the apex information; and a step of referencing the values of the color and brightness from the table based on the address and assigning to each pixel composing the polygon.

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FIG. 1

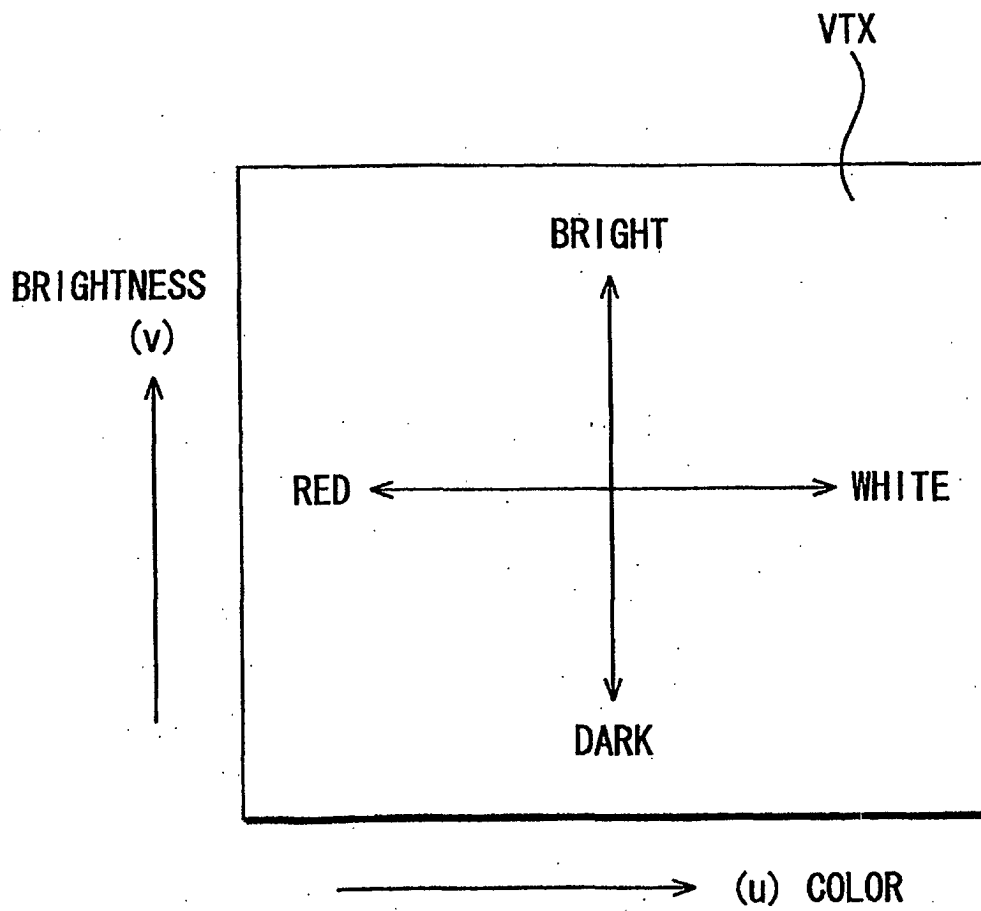


FIG. 2

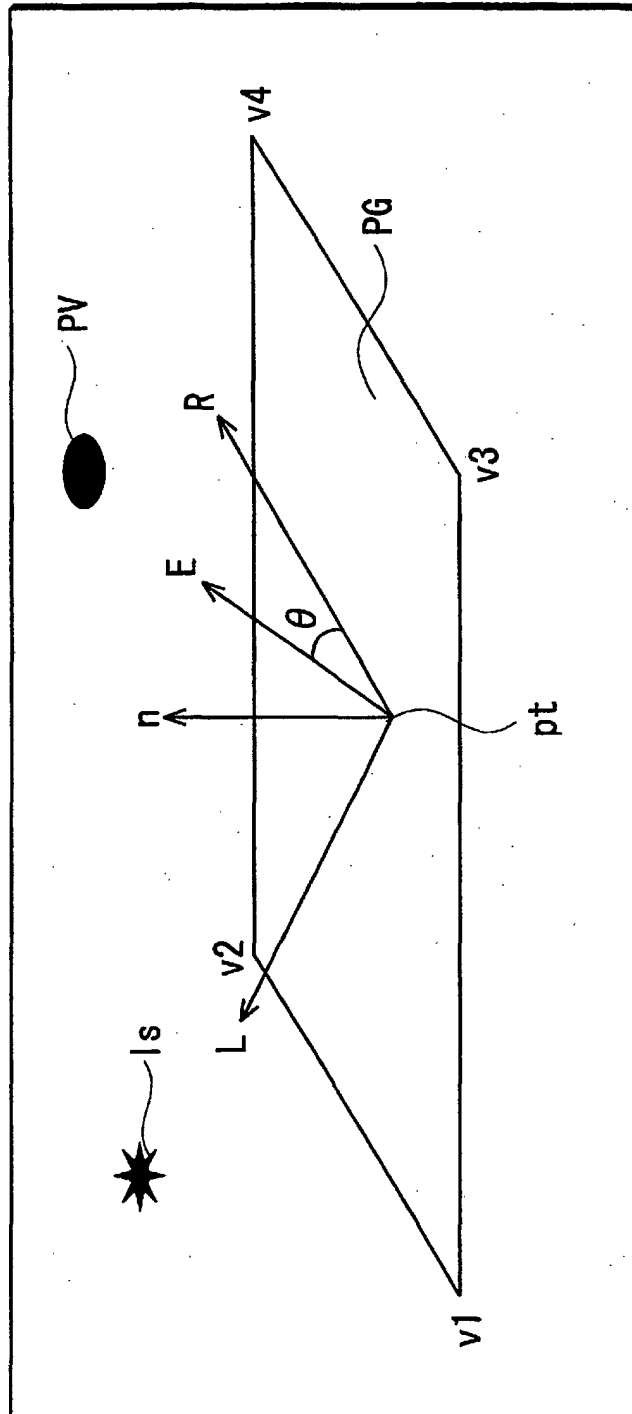


FIG. 3

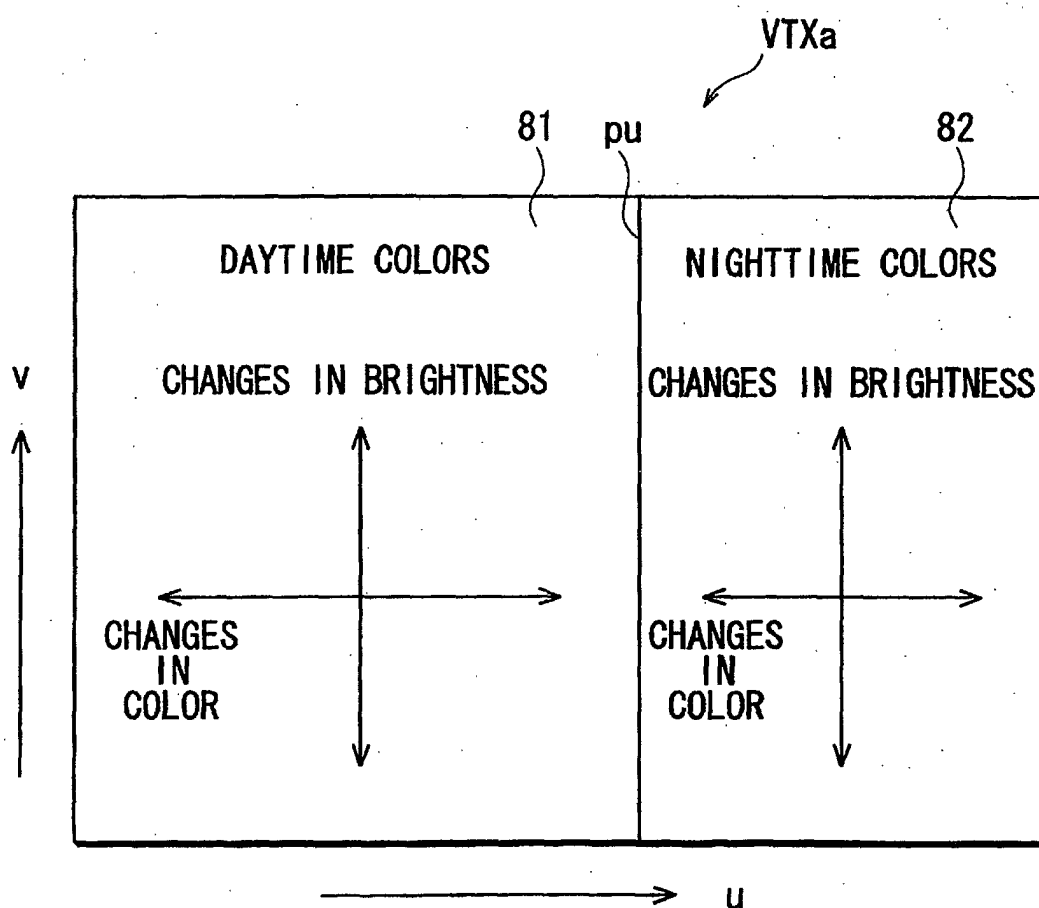


FIG. 4

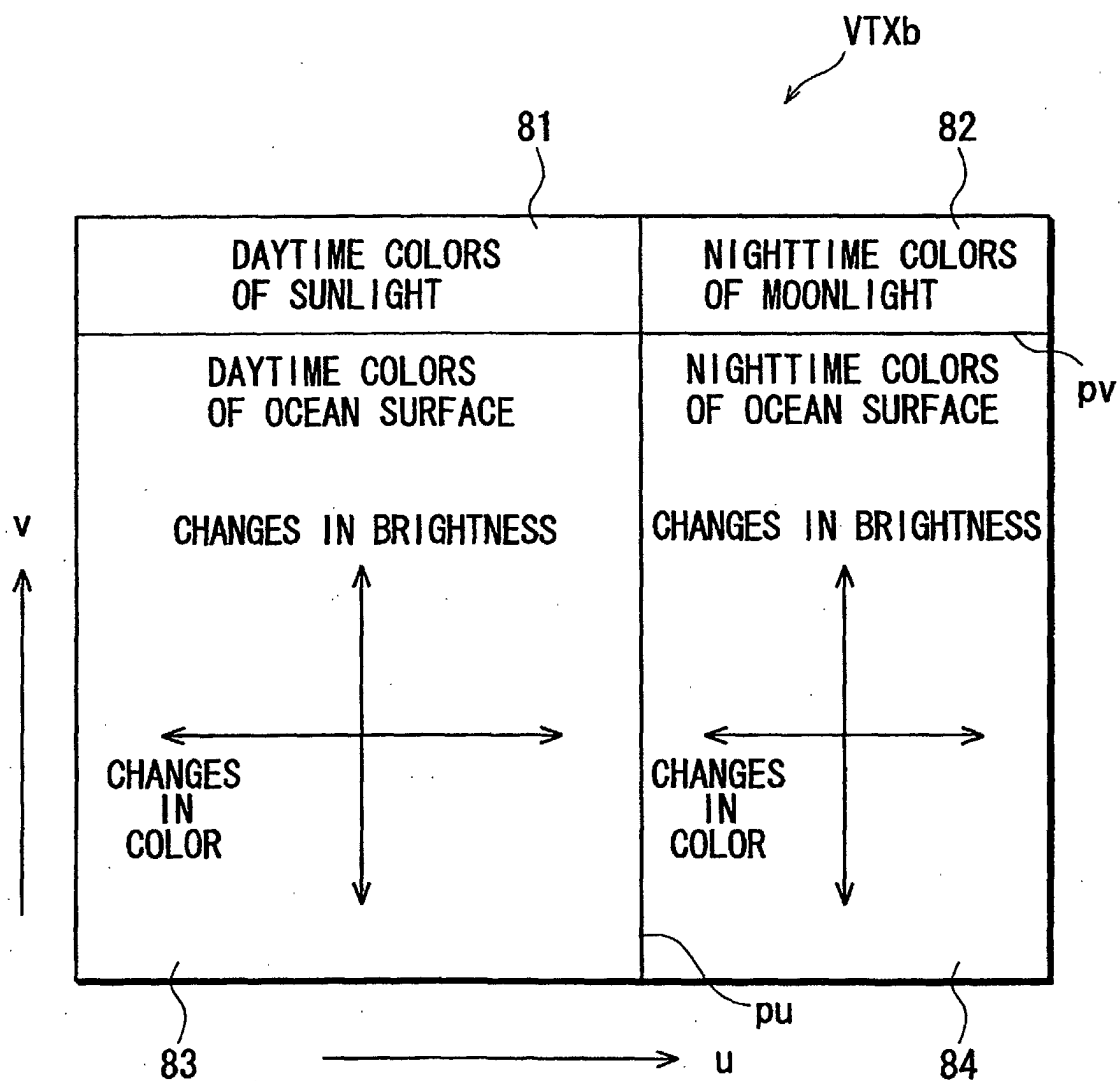


FIG. 5

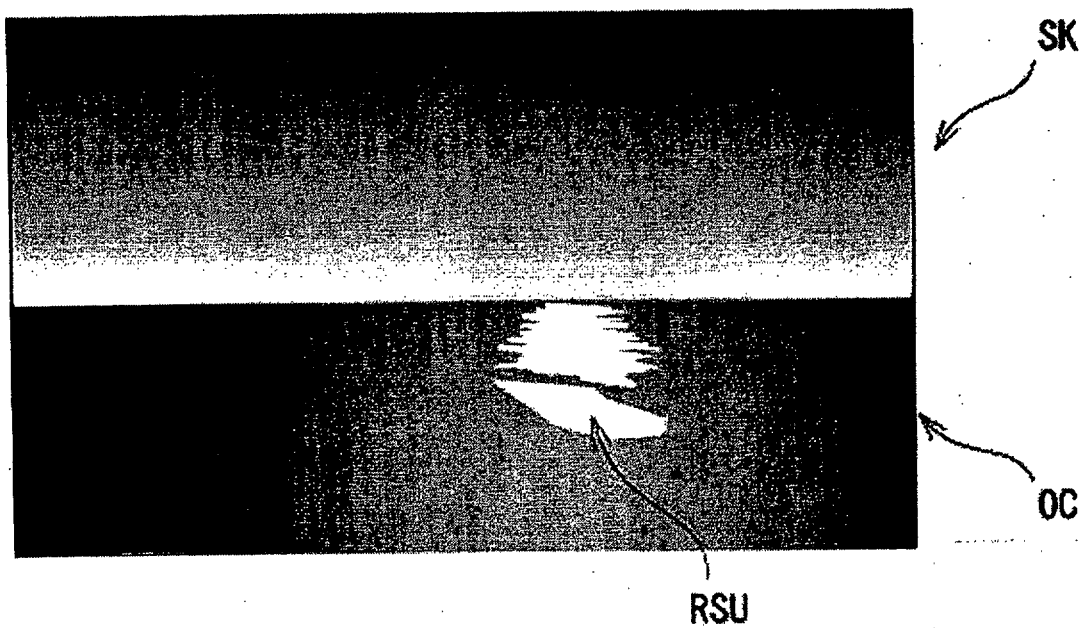


FIG. 6

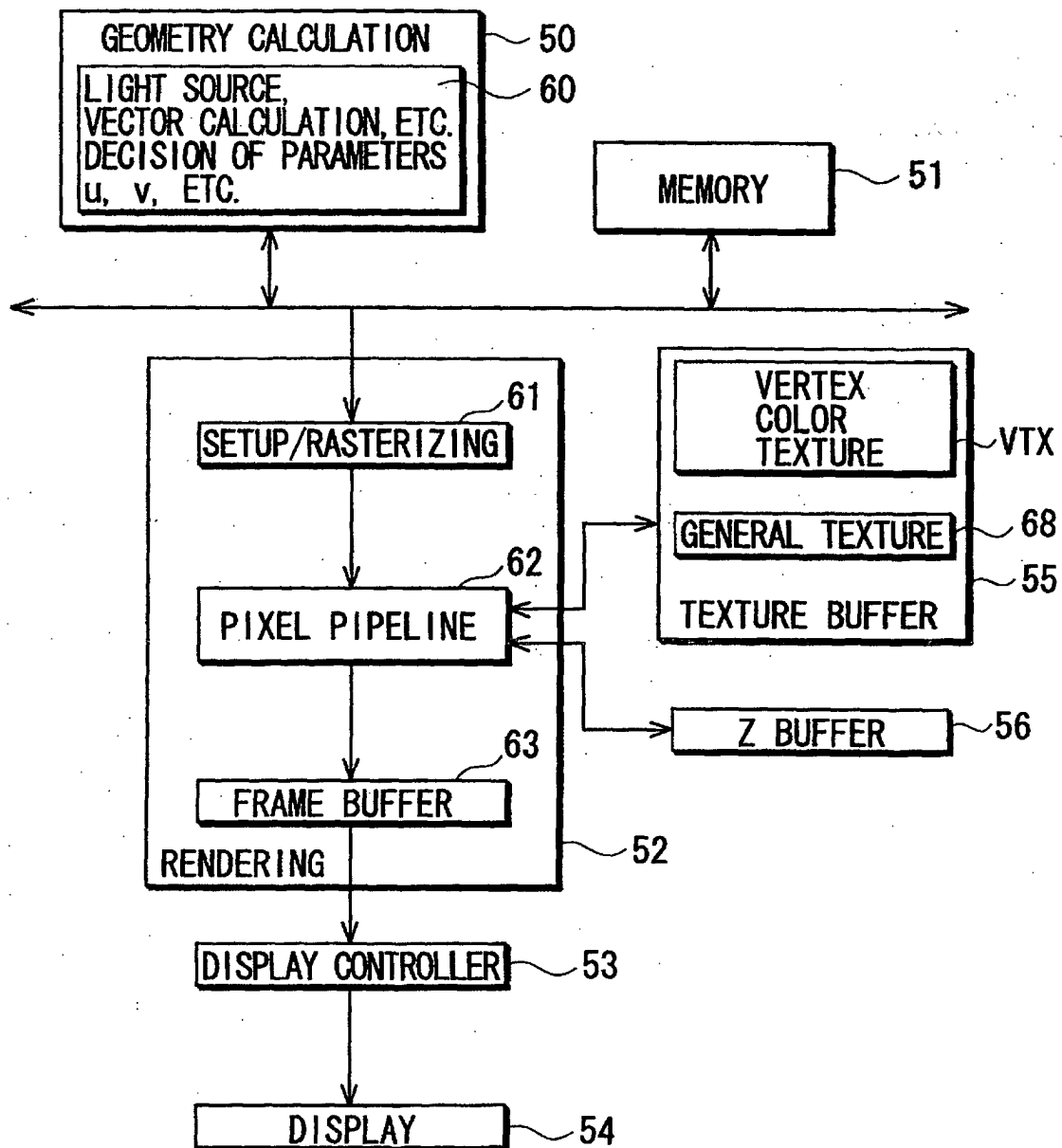


FIG. 7

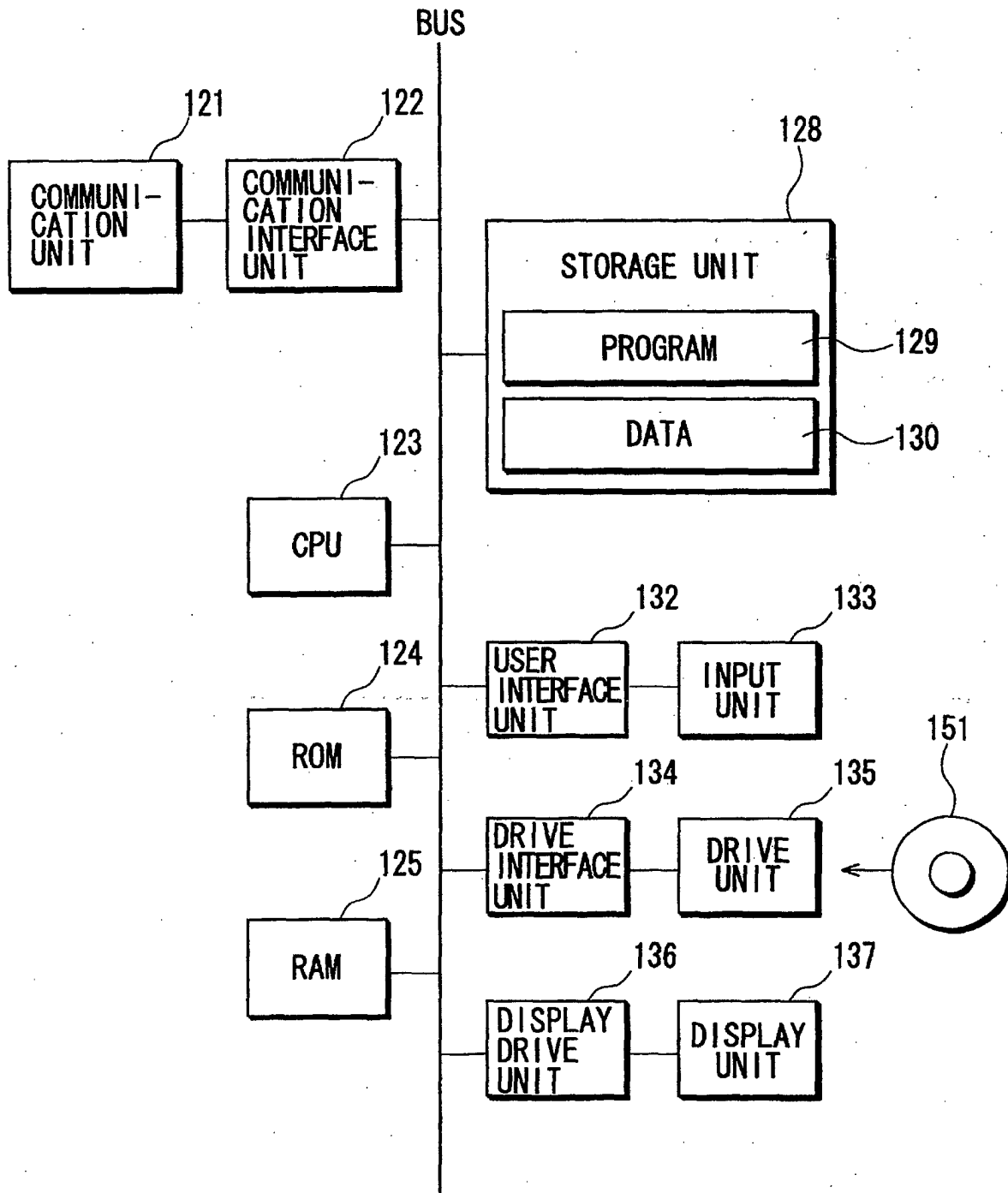
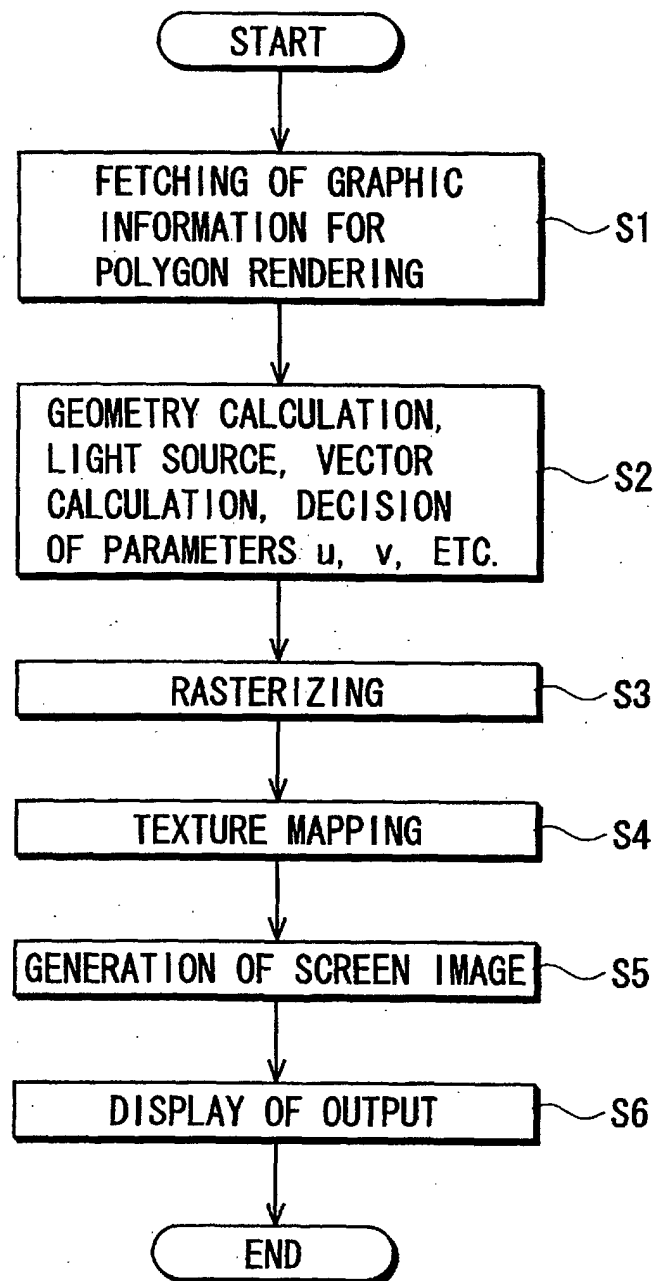


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP02/04543

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ G06T15/00		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl ⁷ G06T15/00-15/60		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Jitsuyo Shinan Toroku Koho 1996-2002 Kokai Jitsuyo Shinan Koho 1971-1996 Toroku Jitsuyo Shinan Koho 1994-2002		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 7-152925 A (Toppan Printing Co., Ltd.), 16 June, 1995 (16.06.95), Full text	1, 3, 6, 7, 8, 10, 13, 14, 15, 17, 20, 21, 22
A	(Family: none)	2, 4, 5, 9, 11, 12, 16, 18, 19
Y	JP 11-195134 A (Hitachi, Ltd., Xanavi Informatics Corp.), 21 July, 1999 (21.07.99), Par. No. [0027]	1, 3, 6, 7, 8, 10, 13, 14, 15, 17, 20, 21, 22
A	(Family: none)	2, 4, 5, 9, 11, 12, 16, 18, 19
A	JP 11-175748 A (Namco Ltd.), 02 July, 1999 (02.07.99), Full text	4-6, 11-13, 18-20
A	(Family: none)	
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 05 June, 2002 (05.06.02)		Date of mailing of the international search report 18 June, 2002 (18.06.02)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)